# Vibrational techniques to assess the initial stability of spherical press-fitted implants: in vitro study

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**INTRODUCTION:** The initial fixation of orthopaedic implants strongly influences the success rate [1], but its objective intra-operative assessment is a challenge, since surgeons have to rely on their clinical experience. Moreover, excessive press-fitting can cause intraoperative fractures [2]. Vibration analysis has been successfully applied to assess the stability of shaft-like implants (i.e. dental implants and femoral stems) *in vitro* and *in vivo* [3, 4]. This paper presents vibrational methods designed to assess the initial stability of spherical implants.

**METHODS:** The glenoidal assembly of reverse shoulder prostheses, hip resurfacing femoral and acetabular implants were studied during an in vitro series of experiments. The study on shoulder prostheses focuses on metal-on-metal fixation whereas the studies on resurfacing implants focus on metal-on-bone fixation. Frequency response function (FRF) graphs and modal shapes between 0 and 20 kHz are obtained for the implants in controlled conditions (free-free situation, various insertion stages, different fixations). Destructive tests to measure the force needed to extract the implant were performed and the results were correlated with the results obtained by vibration analysis.

**RESULTS:** Local modal changes as well as a shift in resonance frequencies indicated the presence of soft tissue presence between the *glenoidal components* of a *reverse shoulder prosthesis*. The resonance frequencies were also a sensitive indicator for the amount of press-fit that was achieved when inserting the *femoral* component of *hip resurfacing* prosthesis (Table 1). The extraction forces and the resonance frequencies corresponding to different fixations could be correlated (Table 2). Local displacements of vibrational modes were influenced by the local contact conditions. The particular FRF reverse shift after the final insertion stage of the *acetabular* component could indicate the endpoint of insertion for this type of implant.

*Table 1. Resonance frequencies corresponding to the 5th vibrational mode of femoral implant measured at different insertion stages*

| Insertion stage | Resonance frequency |
|---|---|
| free implant | 15140 Hz |
| stage 1 | 16590 Hz |
| stage 2 | 17080 Hz |
| stage 3 | 17360 Hz |

*Table 2. Resonance frequencies and the corresponding extraction forces measured for two different fixations of a femoral implant*

| Extraction force | Resonance frequency |
|---|---|
| 267 N | 15920 Hz |
| 1762 N | 17360 Hz |

**DISCUSSION & CONCLUSIONS:** The changes observed in the FRF graphs and modal shapes contain information related to the implant stability. Usually, an increase of resonance frequencies indicates an increasing stiffness of the tested structure, and thus a better stability, while a decrease of resonance frequencies is interpreted as a stability loss. High local modal displacement differences between a stable implant and unstable implant can indicate the area causing the unfavourable implant fixation. The obtained results clearly prove the sensitivity of vibration analysis in assessing the implant fixation. Hence, non-destructive vibrational methods could be valuable tools in taking optimal decisions during orthopaedic surgical procedures.

**REFERENCES:** [1] Mjoberg B. Orthopedics, 1997, 20(12),1165-75. [2] Meek RM. J Bone Joint Surg Am 2004, 86-A:480-485. [3] Meredith N. Clin Oral Implants Res 1997, 8:226-233. [4] Pastrav LC. J Orthop Surg Res 2009, 4:10.

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